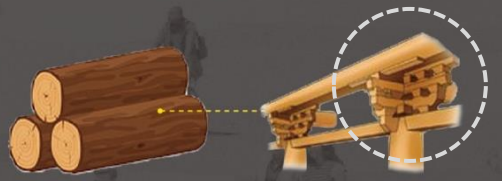
Hybrid Hanok : OUN(悟樓) for Business Incubator Center

MYONGJI UNIVERSITY CAMU AXIAmaterials HAENGLIM 나무텍 U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON

What is the Hanok style?

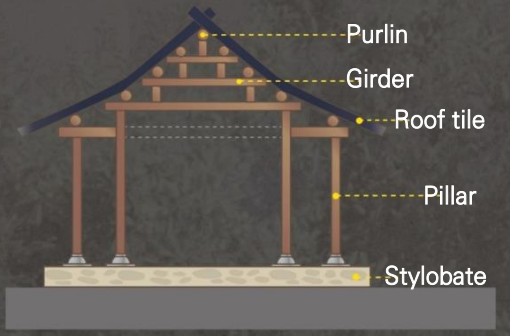
The Hanok, a Korean traditional housing, is under the transformation to "*hybrid Hanok*" for zero-energy performance.

What is the Hanok's materials?



Wood, the main material of Hanok, commits to 40% reduction in carbon emissions by 2030.

What is the Hanok's structure?

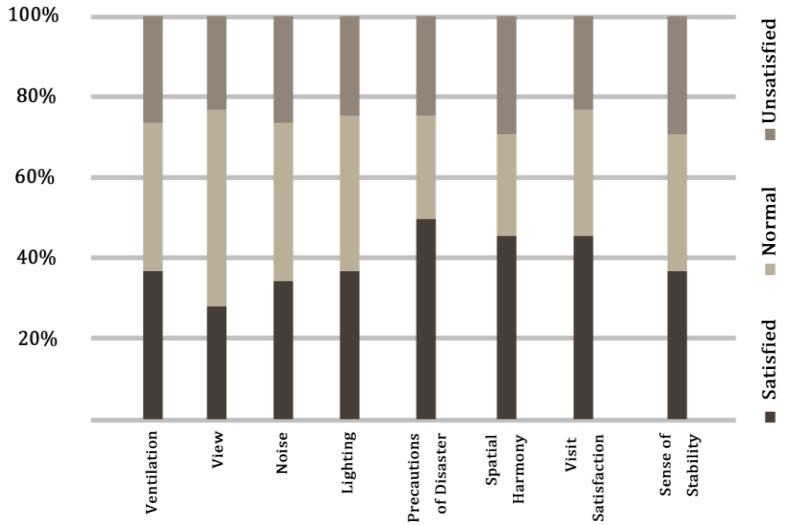


Uniqueness of Korean timber structure in Hanok





Hanok Users' Perceptions and Evaluations



Design Constraints toward Zero Energy Hanok

Roadmap of Zero-energy Building

2020	2025	2030
Public Buildings (Over 1,000㎡)	Civil buildings (Over 1,000㎡) Apartment Buildings (Over 30 households) Public Buildings (Over 500㎡)	All Buildings, (Over 500㎡)

Building Energy Regulations

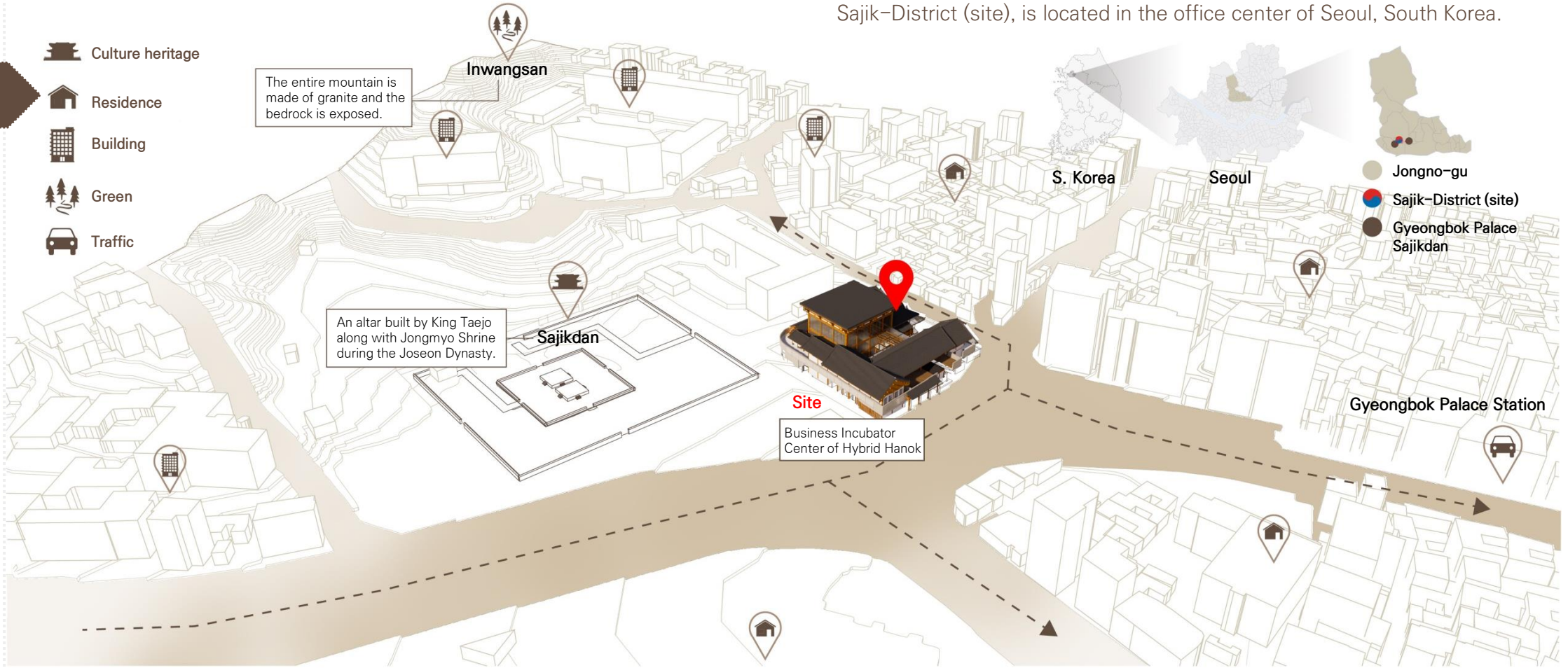
Building Design Criteria for Energy Saving (BDCES)	Mandatory	Mandatory
Prescriptive Method	Present	From 2025
Building Energy Efficiency Certification (BEEC)	Recommendation	Mandatory
Performance Method	Present	From 2025
Zero Energy Building Certification (ZEBC)	Recommendation	Mandatory
Performance Method	Present	From 2025

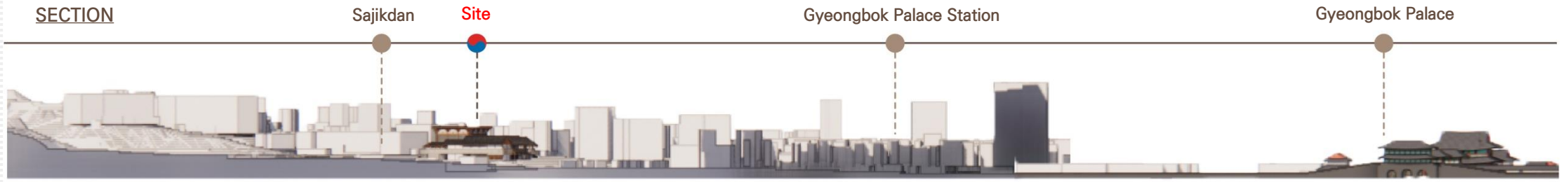
Major Constraints





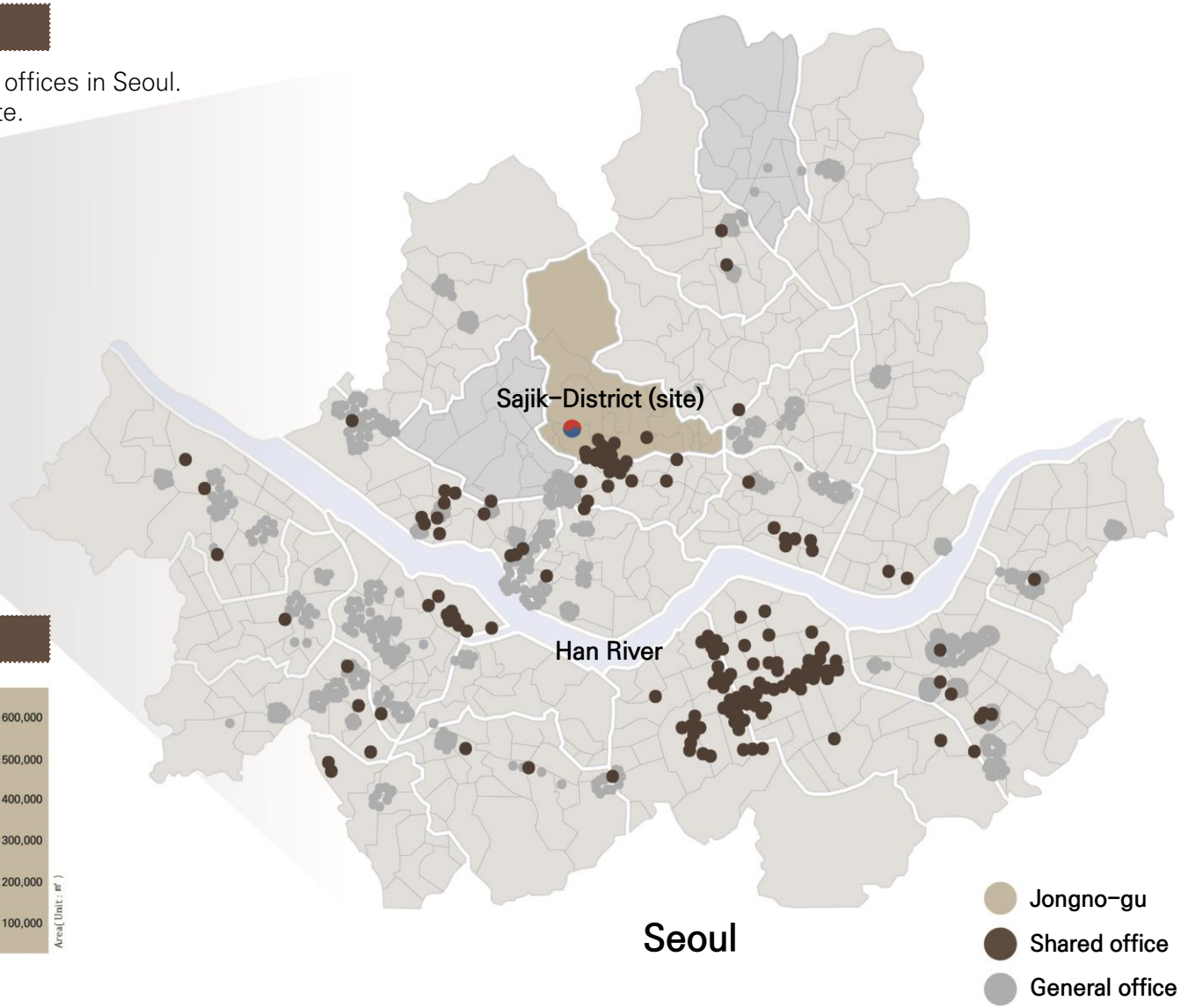
Sajik-District (site), is located in the office center of Seoul, South Korea.



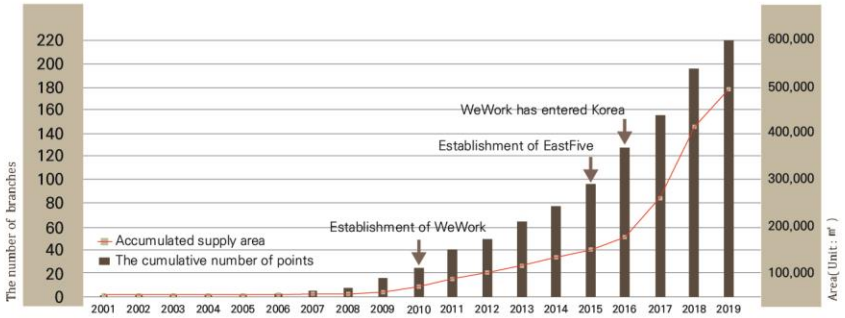


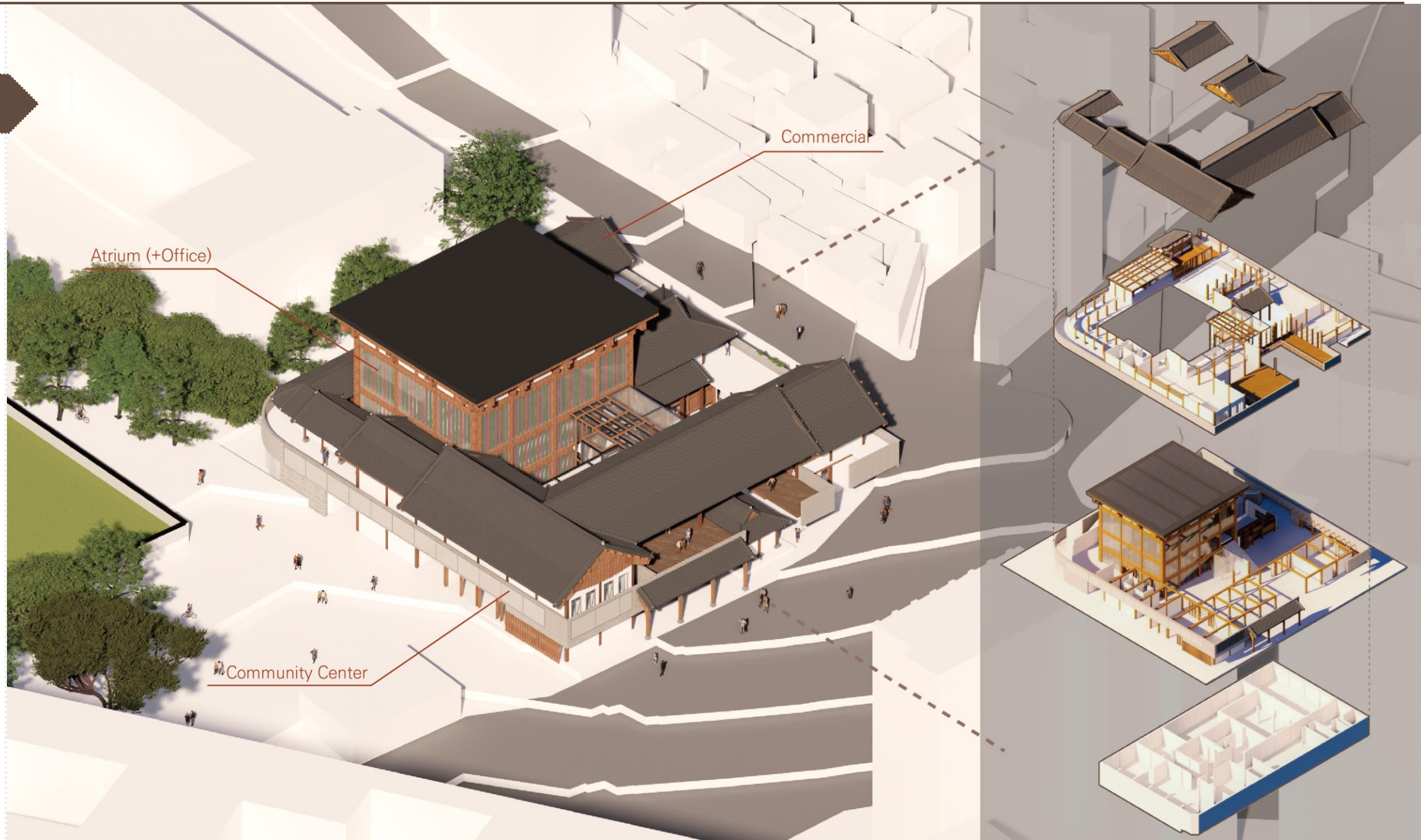
The increasing rate of shared offices in Seoul

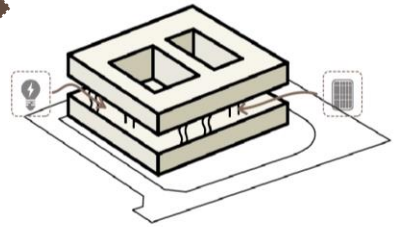
It is showing the distribution of shared offices and general offices in Seoul.
There is no shared office in Sajik-dong, Jongno-gu, our site.



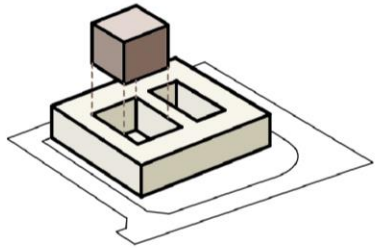
The increasing trend of shared offices in Seoul



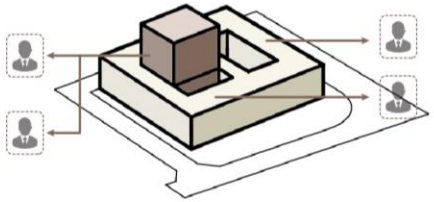




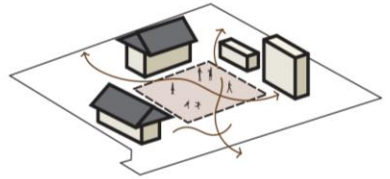
OLD&NEW
FACILITIES



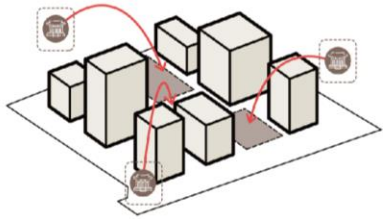
OLD&NEW
ARCHITECTURE



INCUBATING



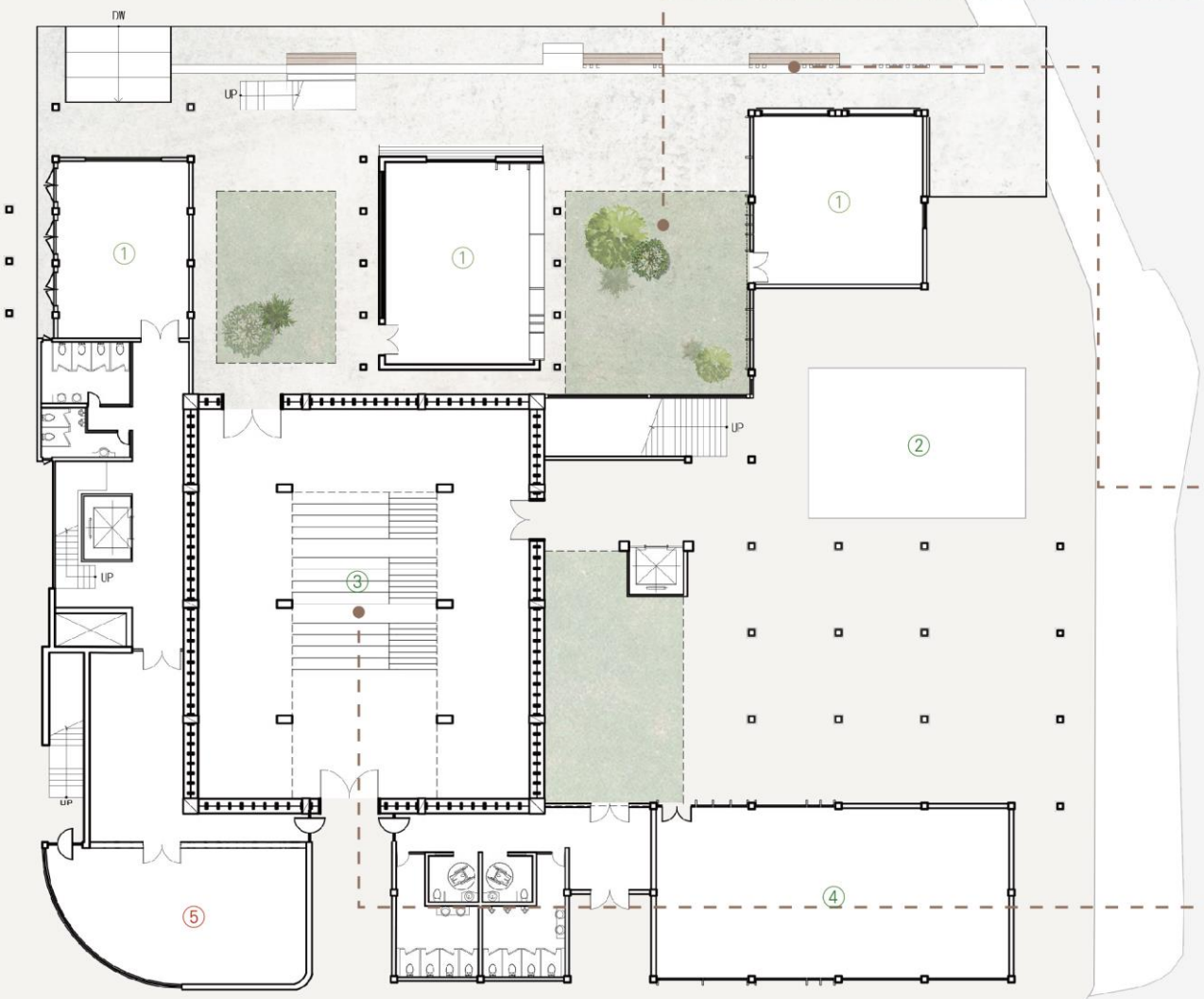
COMMUNITY



MODULIZATION

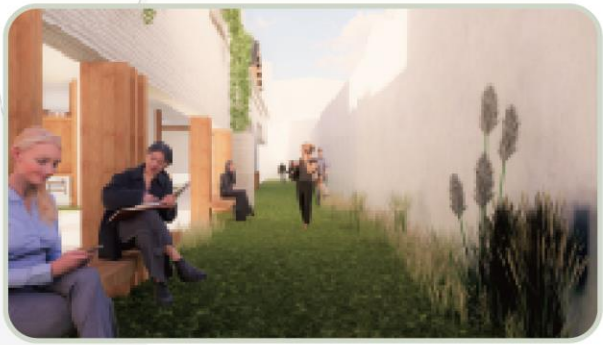
PROJECT DATA

SUBJECT	DETAILS
Location	1-28, Sajik-dong, Jongno-gu, Seoul, South Korea
Climate	Hot & Humid (Summer) and Cold & Dry (Winter), Similar to the U.S climate Zone 4A
Total Floor Area and Unit Area	4,136 m^2 (44,527 ft^2)
The Total Floor Area Ratio of Office to Non-office Space	53.6% (office) : 46.4%(non - office)
Space Use and Occupancy	Office, Atrium Office, Commercial, Community Center
Target Site EUI	Shared offices, Business incubator center, retail shops, community center, Historic site
Target Source EUI	Site EUI 129kWh/m^2yr (40.9 kBTU/ft^2yr), Source EUI 187kWh/m^2yr (59.3 kBTU/ft^2yr)
Construction Cost	USD 18,811,201 ($4,500/$m^2$, 420/$ft^2$)



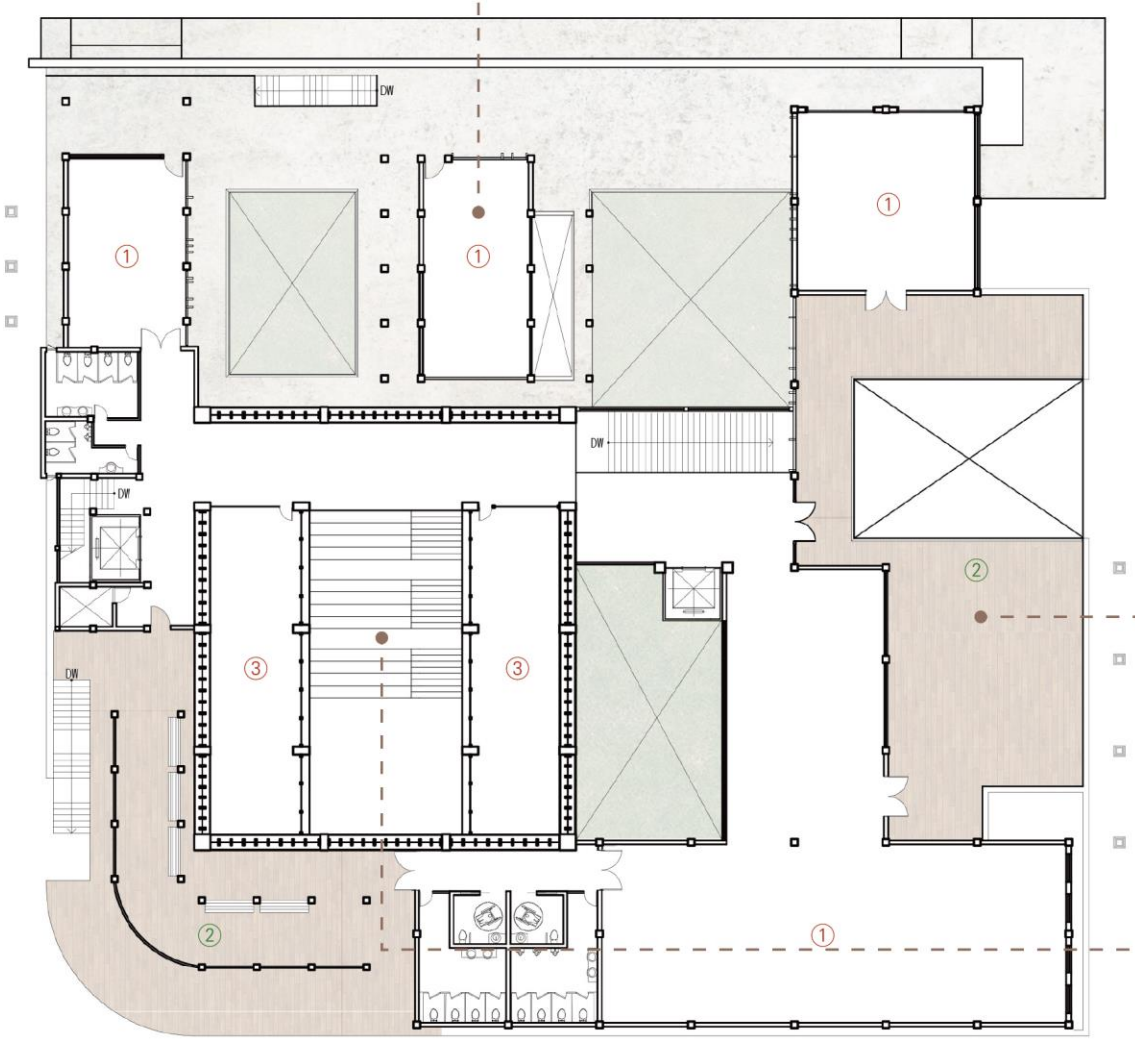
① Commercial ② Historical site (Ahnhyangcheong) ③ Atrium
④ Community sevice center ⑤ Office

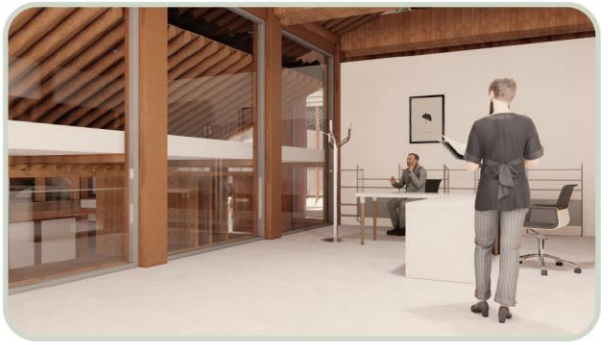
Public space



Open space

Staircase seating area in atrium



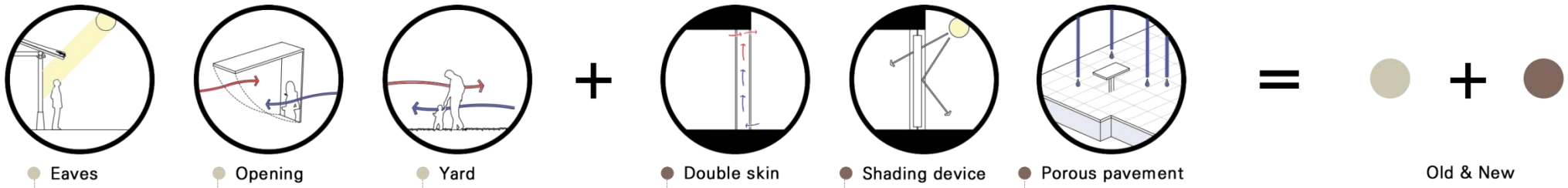


Shared office

Terrace connected to the historical site

Business incubator office

① Office ② Terrace ③ Atrium Office



Fire Safety Treatments

Eco-friendly Flame Retardant

Fire retardant treated wood provides benefits like a significantly slower ignition time, less smoke production, and no flaming droplets.

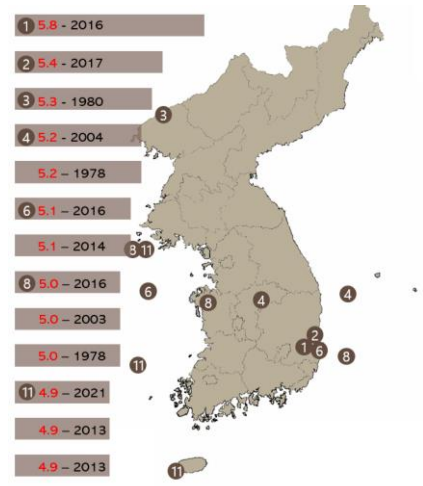
Minimize Toxic gas

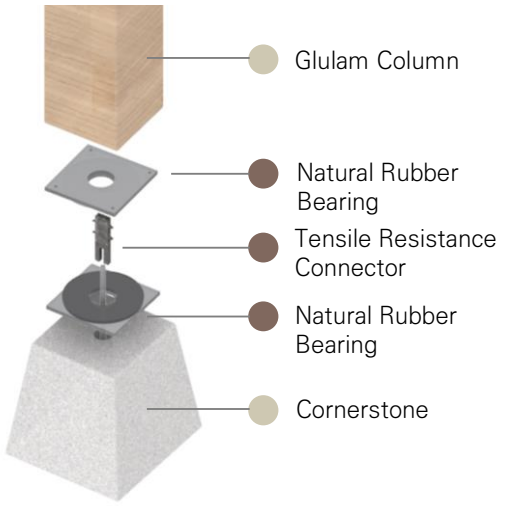
The internal finishing materials are made of wood to minimize toxic gas emissions.

Heavy-Timber

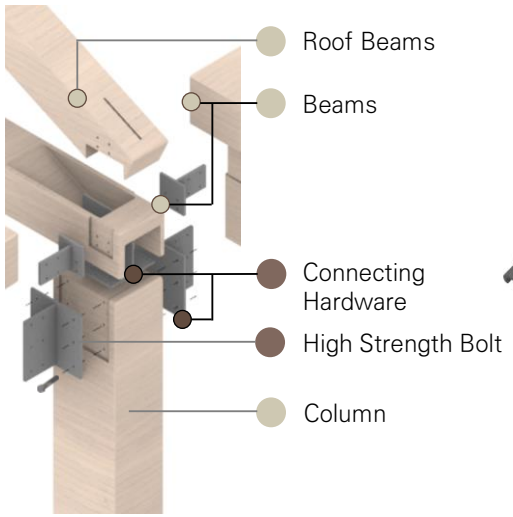
Glulam beams and columns have given three off-the-shelf structural connectors a minimum one-hour fire rating, opening new opportunities for mass-timber construction in buildings.

Frequency of Seismic Events

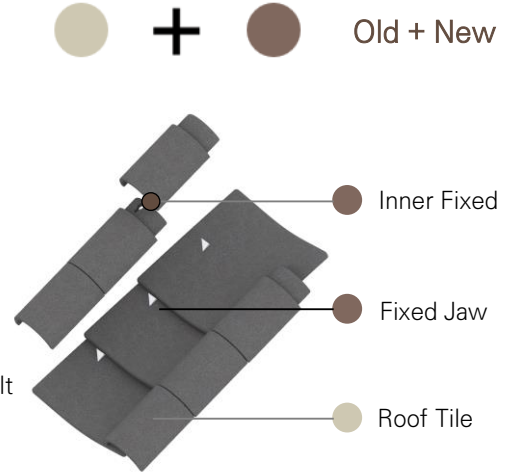




Cornerstone + Column



Column + Beams



Roof Tiles

H-Shaped Column

Cross Sectional Area
Existing = Proposed

However,

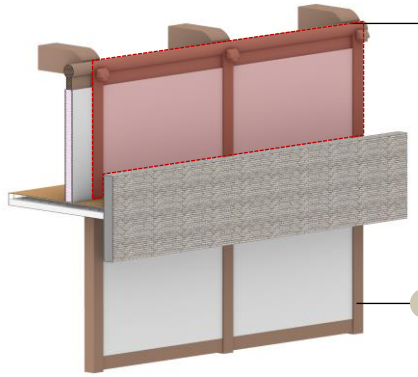
Bending Performance

Existing 〈 Proposed
(20.9 %▲)

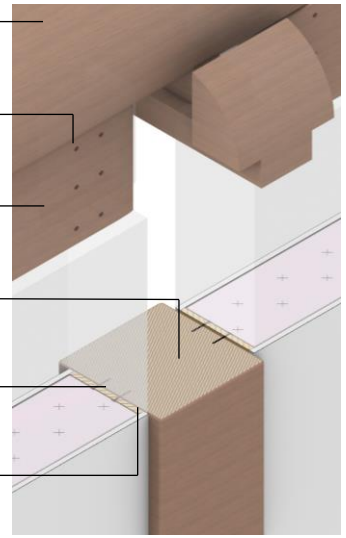
Airtightness, Thermal break

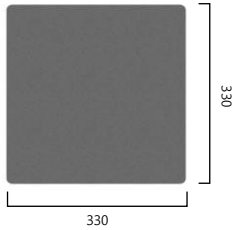
Existing 〈 Proposed

Existing Design (Square Column + Walls)



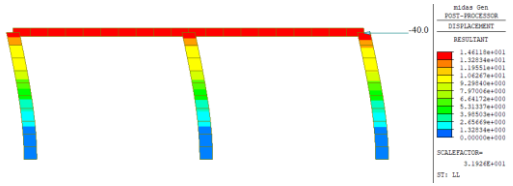
Wooden Beam
Connecting Hardware
Wooden Beam
Existing Column
High Strength Bolt
Stud



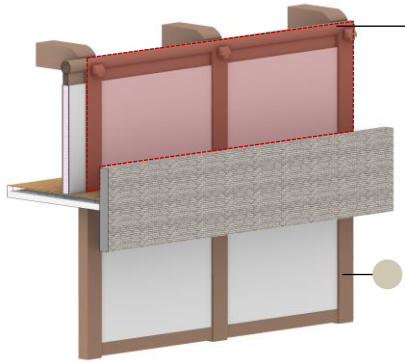


Cross-section $330mm \times 330mm$

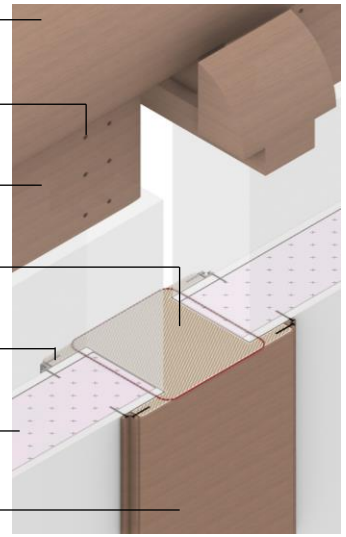
Bending Performance $\frac{bh^3}{12} = \frac{330 \times 330^3}{12} = 9882.68 \times 10^6$

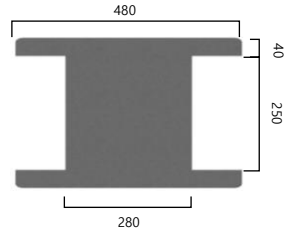


Proposed Design (H-Shaped Column + Walls)



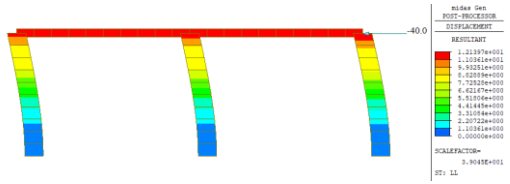
Wooden Beam
Connecting Hardware
Wooden Beam
H-Shaped Column
High Strength Bolt
Composite-Structural Insulation Panel
Column



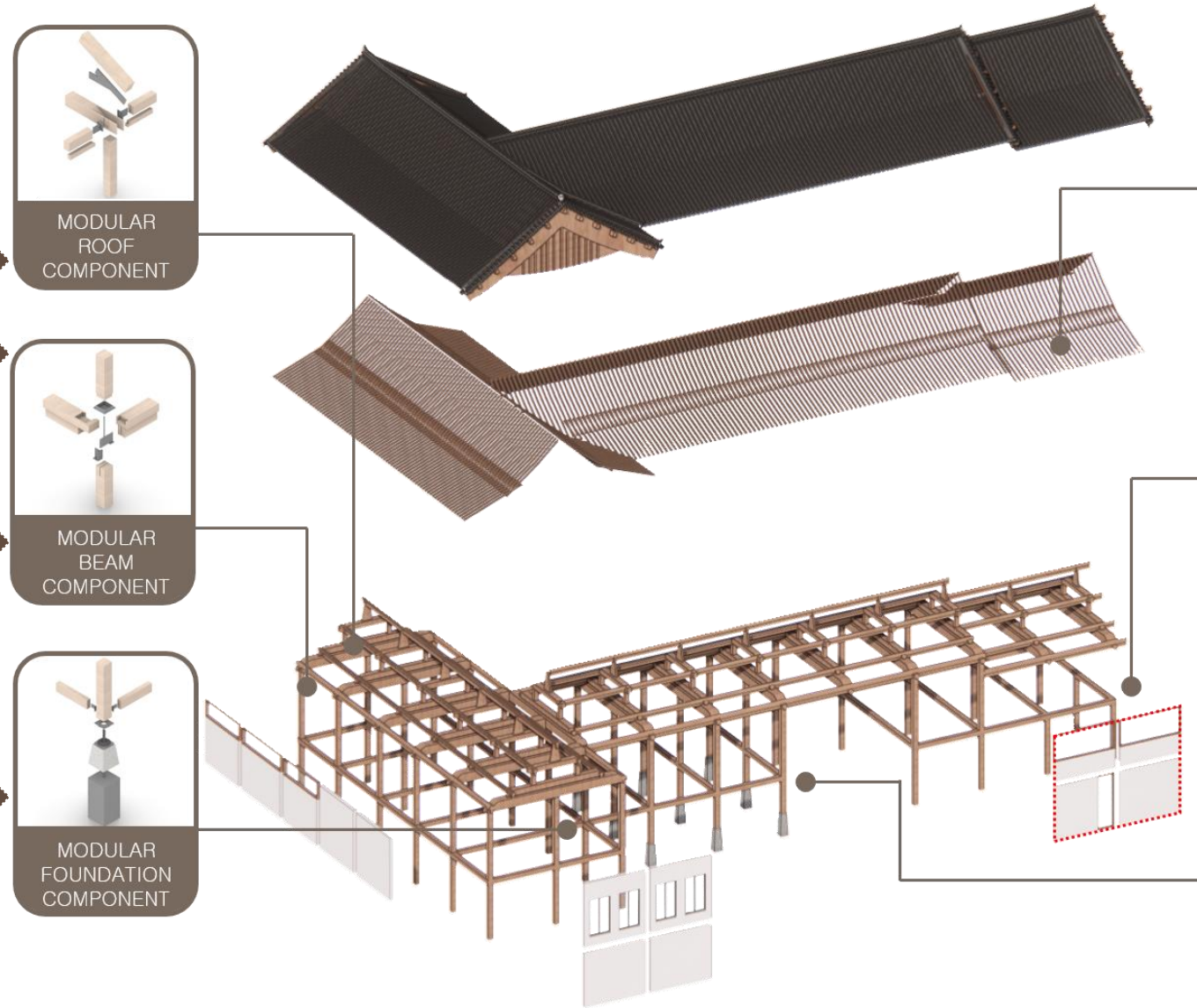


Cross-section $480mm \times 40mm \times 2$
$280mm \times 250mm$

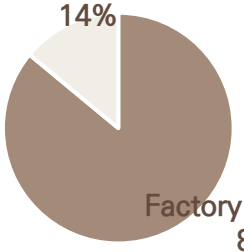
Bending Performance $\frac{bh^3}{12} = \frac{40 \times 480^3}{12} \times 2 + \frac{250 \times 280^3}{12} = 11946.13 \times 10^6$



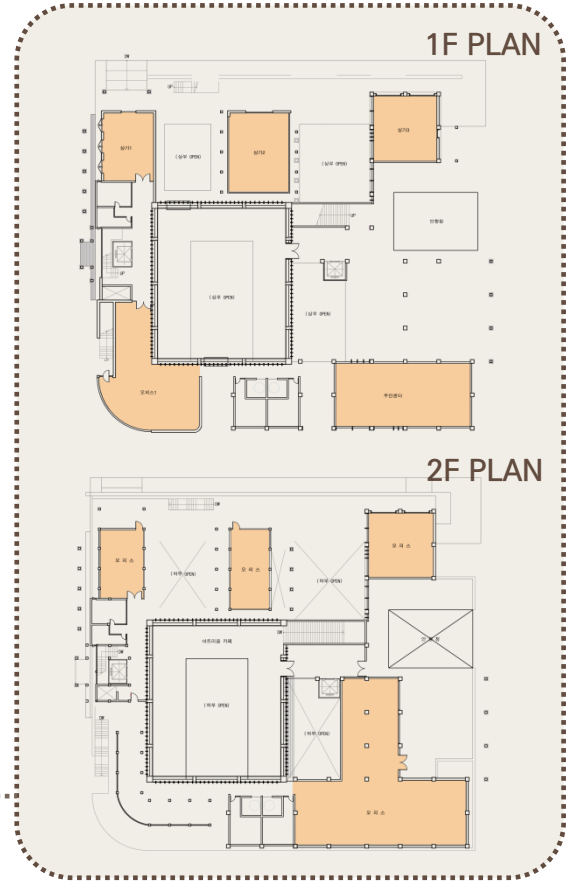
Standardized Element Location



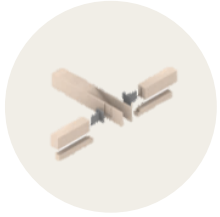
On-site construction



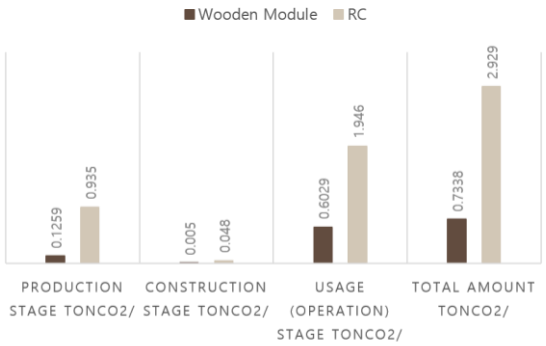
Applied areas of box modular structure



KYUNGMIN Industry – GLT / GLULAM


25%
CO2 Emission Reduction compared to RC

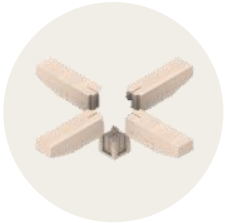


The number of waste wood recycling companies in Korea. (Source: Korea Wood Recycling Association)

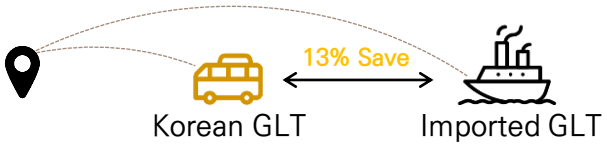
Hwacheon Wood Science Complex

Korea Forest Cooperative Federation Wood Distribution Center

- Deciduous wood wallboards, Board siding, Deciduous wood collecting boards



13%
CO2 Emission Reduction compared to imported products



Hybrid Window Ventilation System

- Apply to windows

UFAD (Underfloor air distribution)

- Apply to office floors

ERV (Energy Recovery Ventilator)

- Apply to underfloor

ESS (Energy Storage System)

- Apply to basement MEP rooms

LED lighting

- Apply to ceiling lighting

Chilled Beam

- Apply to office ceiling

BIPV

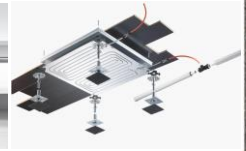
- Apply to roof, wall, shading louvers

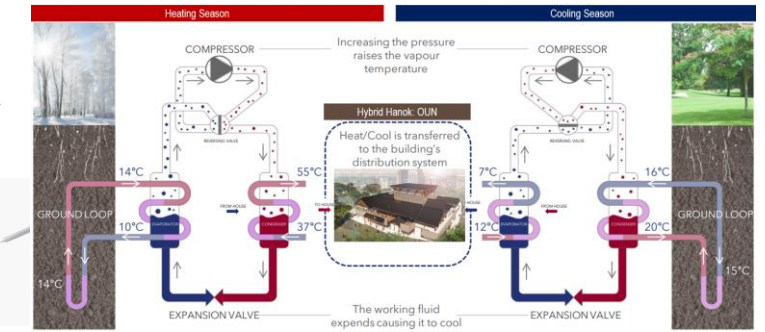
Integrated Piping System

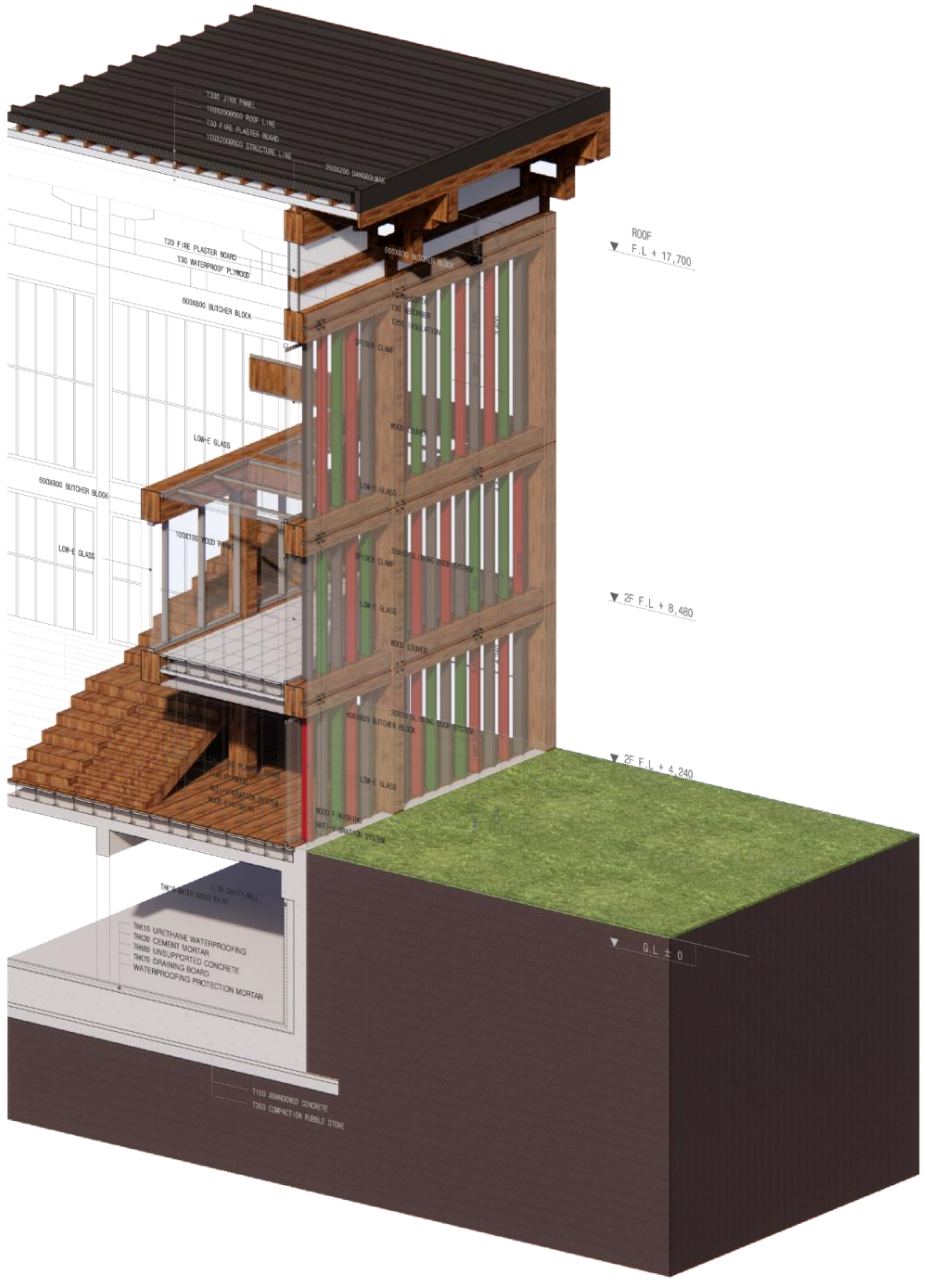
- Apply to water sink

Geothermal Heat Pump

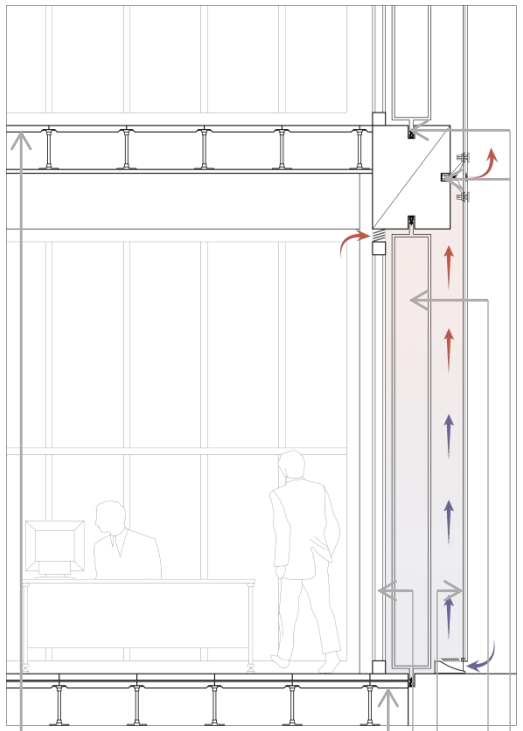
- Apply to basement MEP rooms



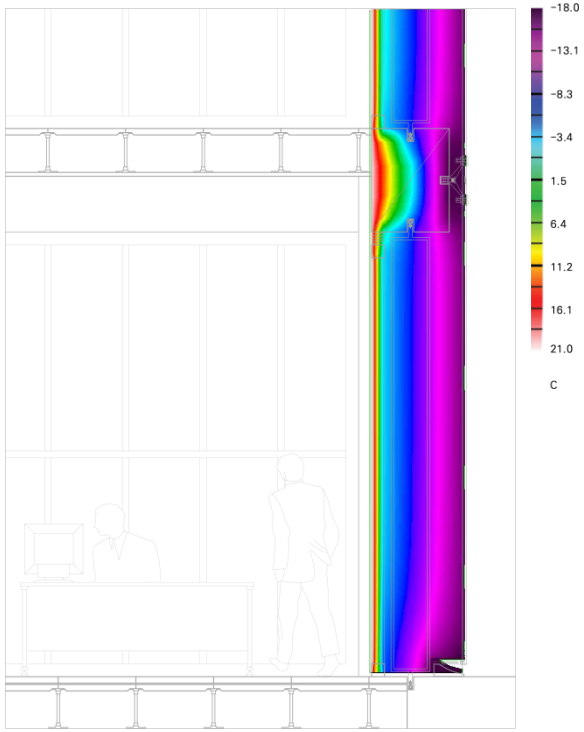




DSF 2D Section



DSF 2D THERM Simulation

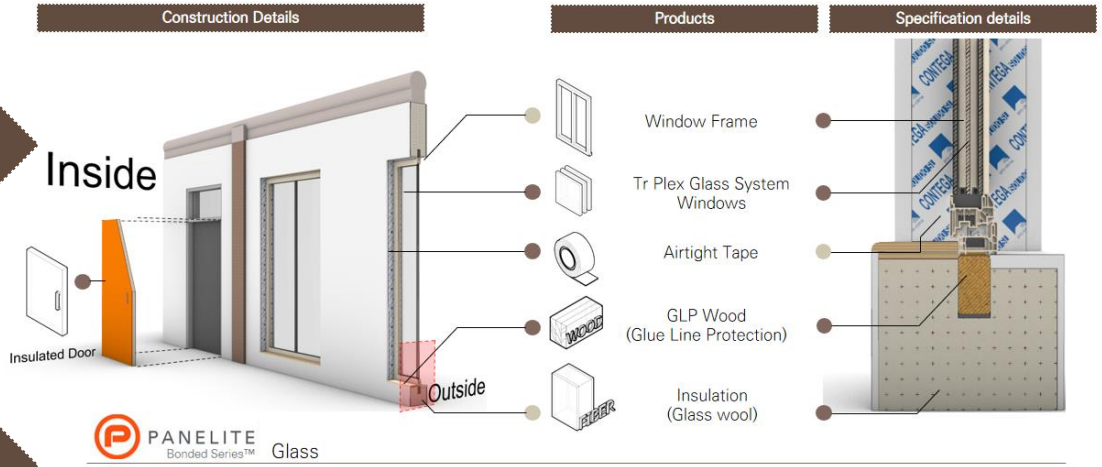


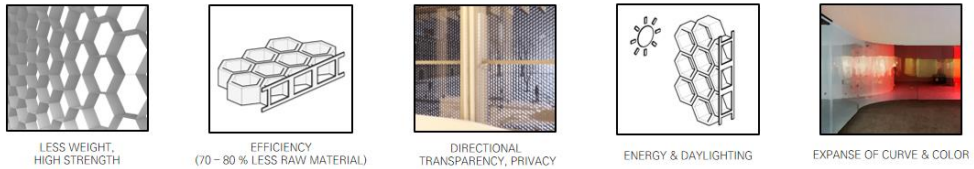
T30 FIRE PLASTER BOARD
T140 PLYWOOD

ANTI-VIBRATION SYSTEM
WOOD FINISHING

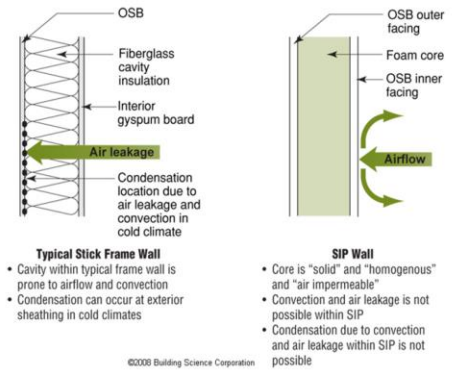
VERTICAL SHADING LOUVER PIVOT
SPIDER CLAMP
PV-INTEGRATED VERTICAL LOUVER (SINGLE-AIXS)

OUTSIDE : 6.4mm SINGLE PANE LOW-E GLASS
INSIDE : 24mm DOUBLE PANE LOW-E GLASS
(16mm ARGON FILLED CAVITY)





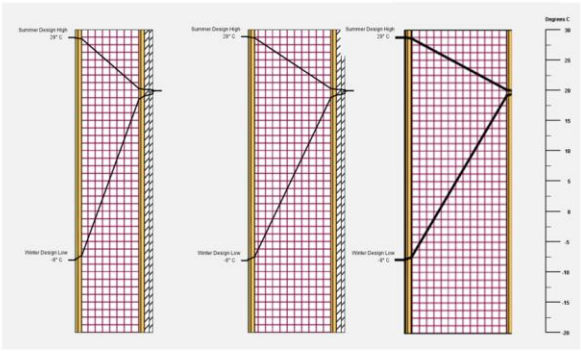
Composite Structural Insulated Wall Panel (C-SIP)



Typical Stick Frame Wall
- Cavity within typical frame wall is prone to airflow and convection
- Condensation can occur at exterior sheathing in cold climates

SIP Wall
- Core is "solid" and "homogenous" and "air impermeable"
- Convection and air leakage is not possible within SIP
- Condensation due to convection and air leakage within SIP is not possible

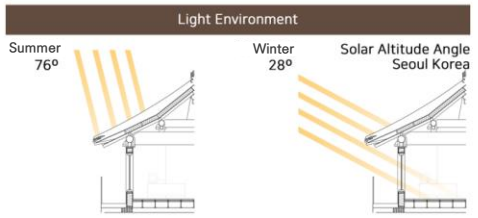
U-Value according to wall insulation thickness



Wall U-Value target		
Overseas average case	Traditional Hanok	Hybrid Hanok taget
0.105W/m²K	3.525W/m²K	0.150W/m²K

Insulation thickenss / U-Value		
150mm	200mm	250mm
0.154W/m²K	0.118W/m²K	0.095W/m²K

Light Environment

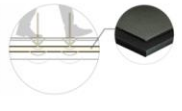


Sound Environment

Wall - STC(Sound Transmission Class) - 59

Floor - Soundproof borad

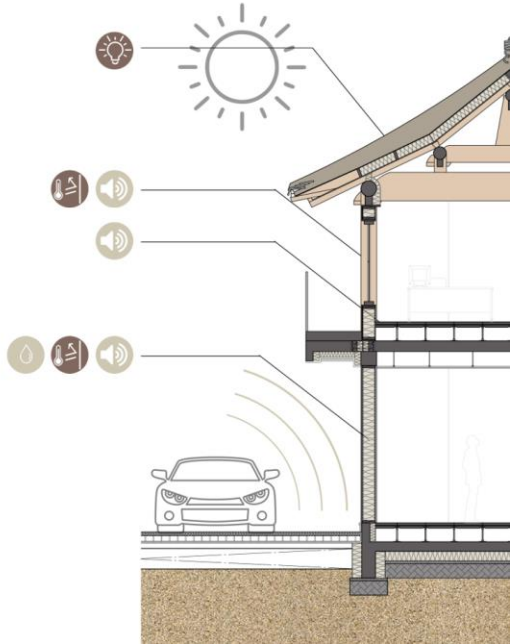
Sound Transmission Class (STC)	Hearing Quality Through Wall
25	Normal speech understood quite easily and distinctly through wall
30	Loud speech understood fairly well, normal speech heard but not understood
35	Loud speech heard but not intelligible
40	Onset of "privacy"
42	Loud speech audible as a murmur
45	Loud speech not audible, 90% of statistical population not annoyed
50	Very loud sounds such as musical instruments or a stereo can be faintly heard, 99% of population not annoyed

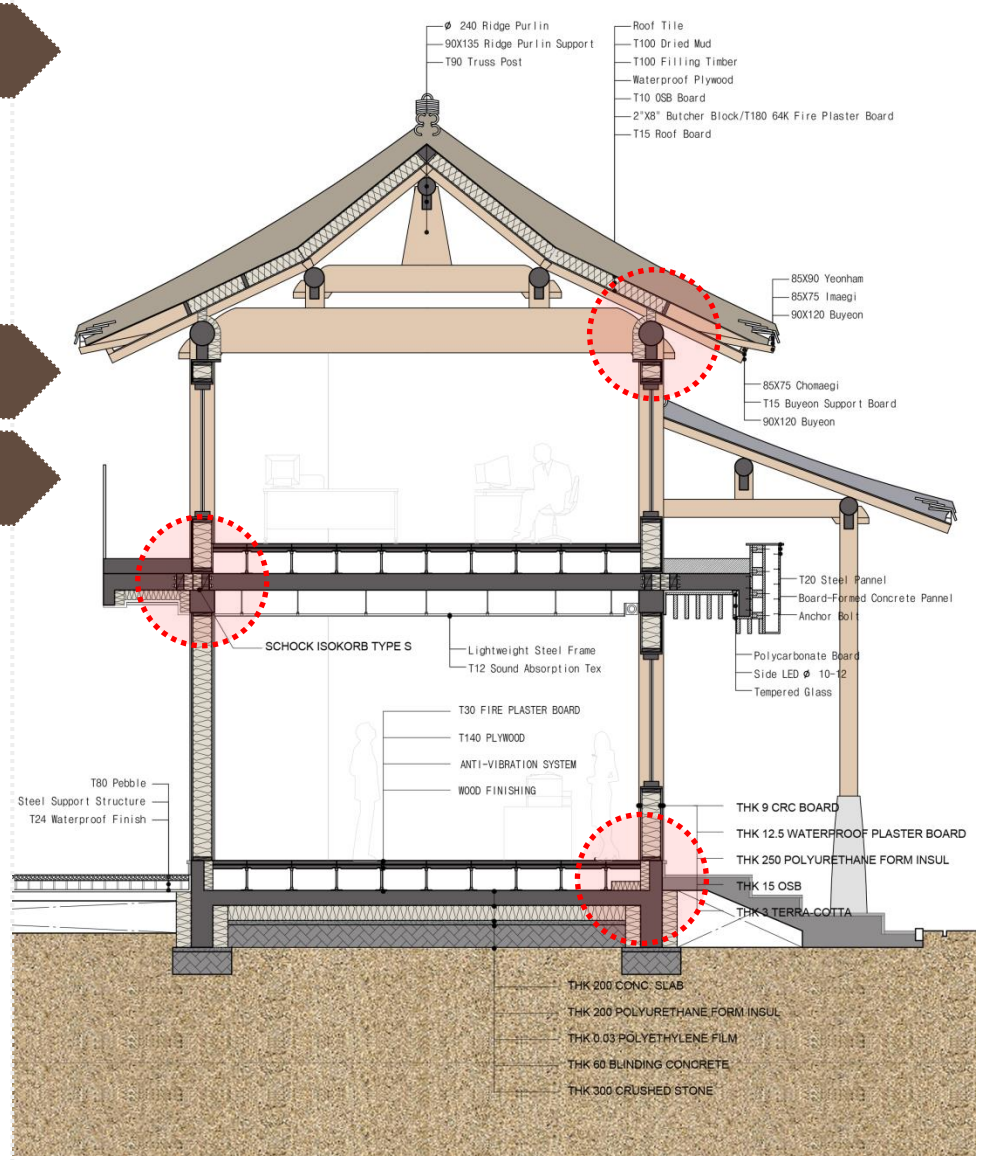


Heat Environment / Moisture

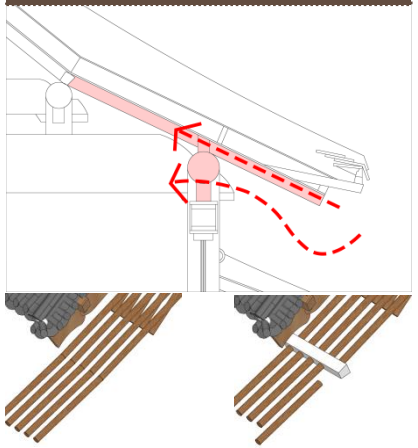
C-SIP Wall THK 200 : Uvalue = 0.118W/m²K

Outside Skin Properties		
Type: Iso-Polyester Thermoset Composite		
Thickness	3/16"	
Reinforcing	Biaxial Fiberglass Mat	
Frame Spread	40	ASTM E-84
Water Resistive Barrier	Grade A	ASTM E-96-05
Vapor Retarder	0.94 perms	ASTM E-96-05
UV Exposure	Pass	ICC-ES AC 38
Accelerated Aging	Pass	ICC-ES AC 38
Water Resistance	Pass	AATCC-127
Coefficient of Expansion for Core and Facings	Pass	ASTM C-393

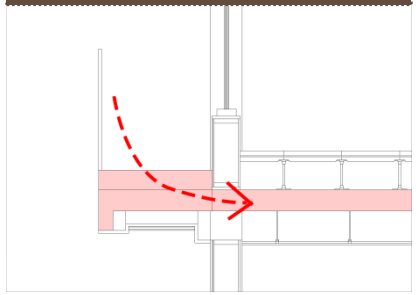




Existing roof section

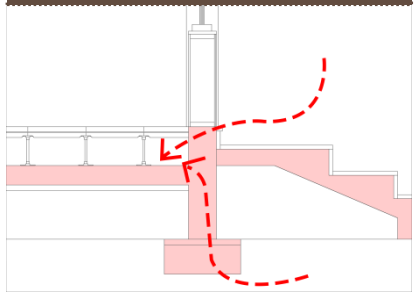


Existing balcony section

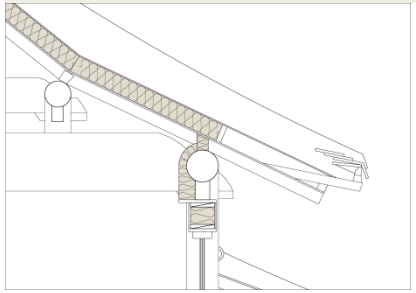


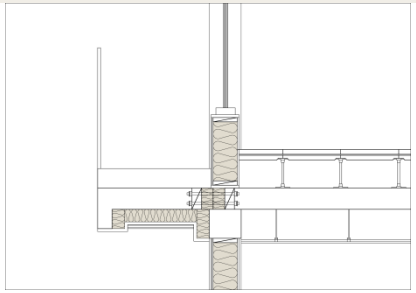
Schock isokorb type s

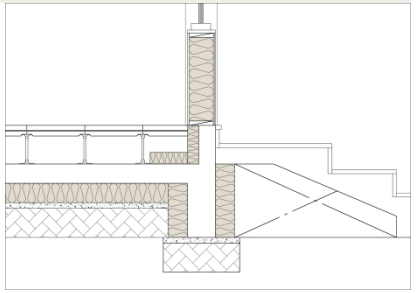
Existing foundation section



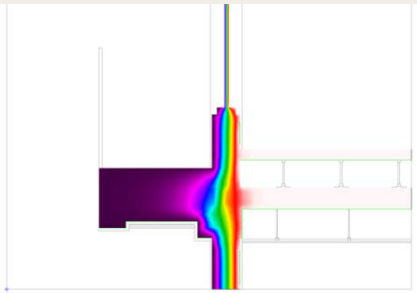
Applications of continuous insulation

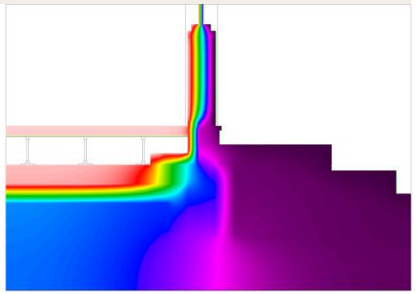




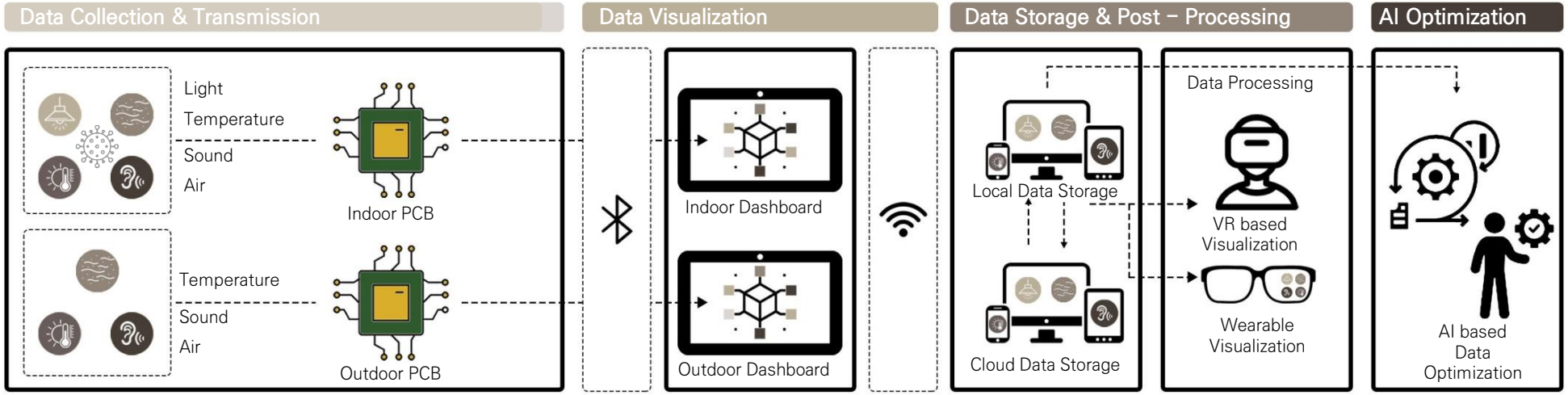


THERM Simulation

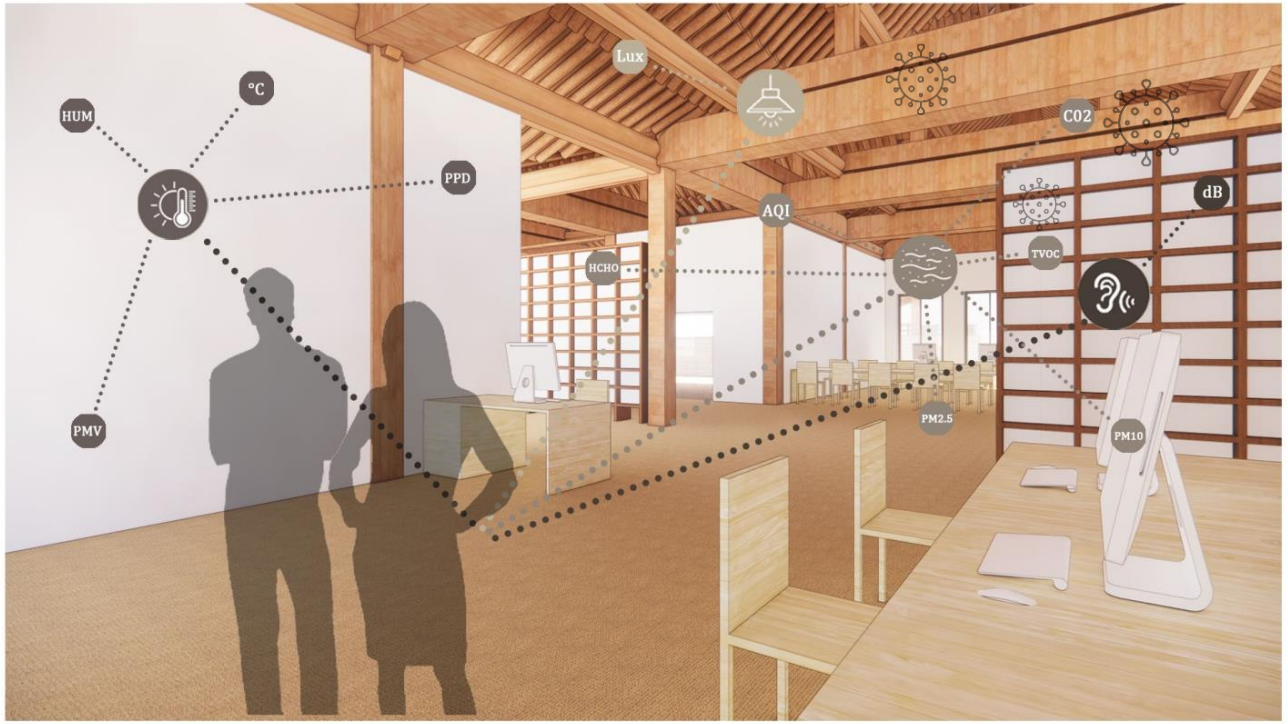


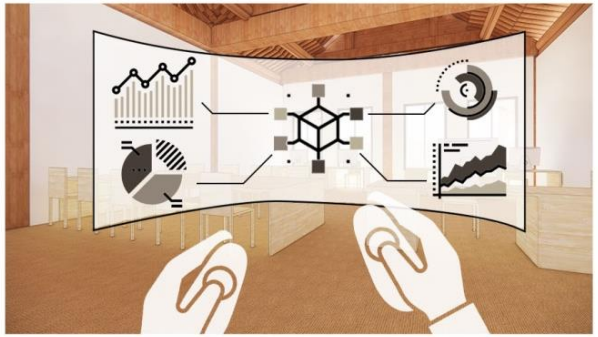


IOT Application Scheme



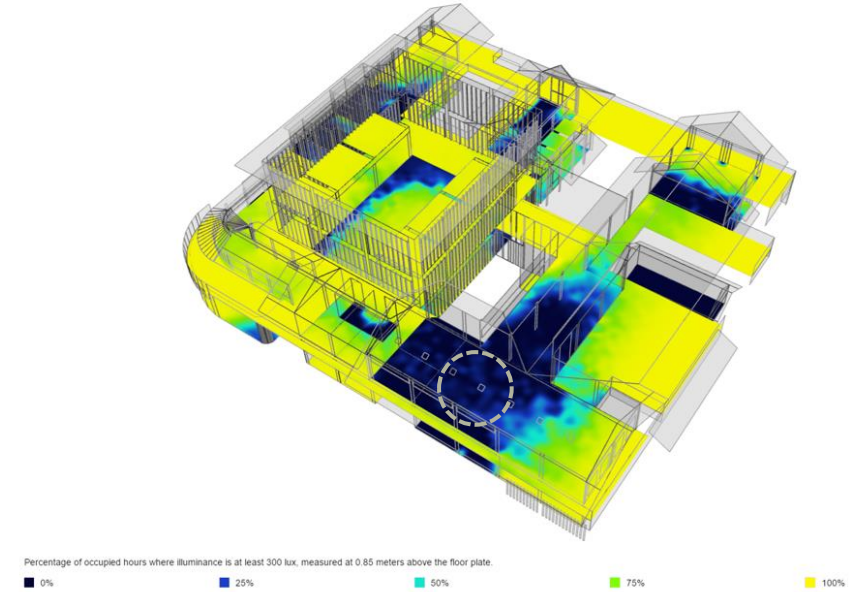
Real-time IEQ Monitoring and Visualization



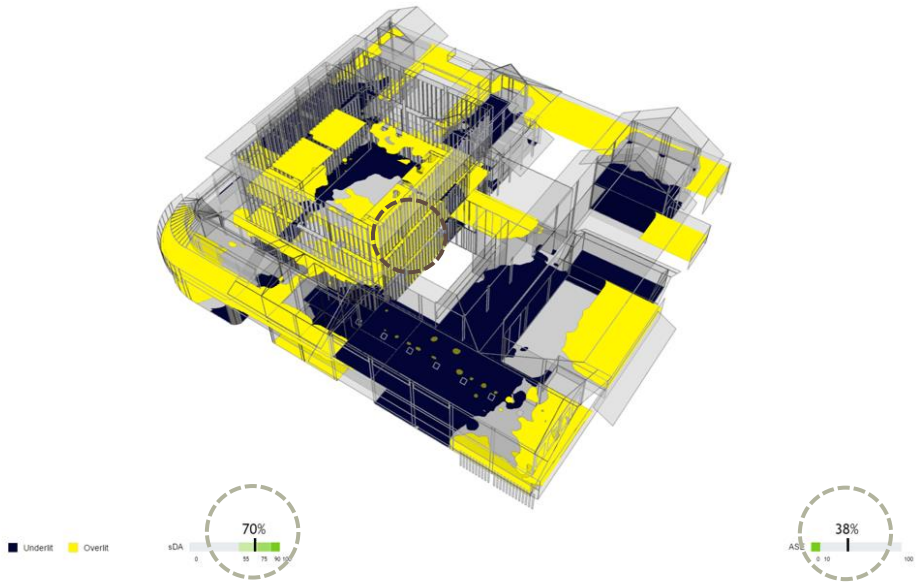


Daylighting

% of occupied hours with at least 300 lux



% of floor area with at least 300 lux for 50% of the annual occupied hours

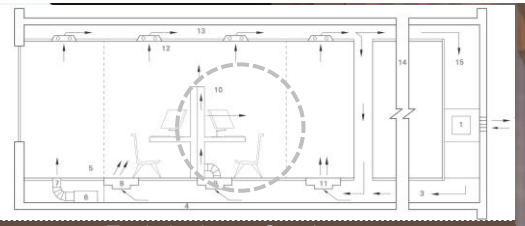


Electrical Lighting

Illumination levels of shared office in 1st Floor

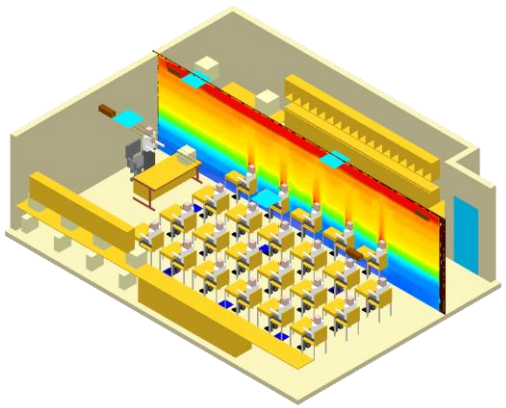
Illumination levels of shared office in 2nd Floor

Under Floor Air Distribution

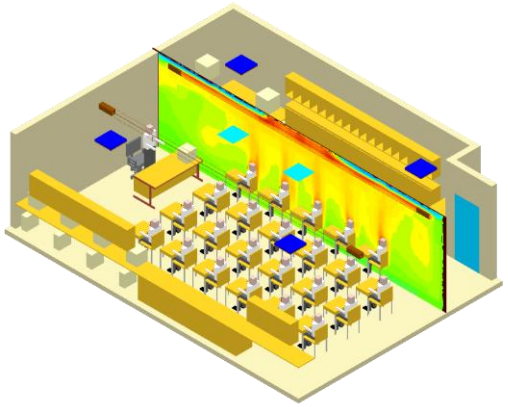


Task Ambient Conditioning

Under Floor Air Distribution

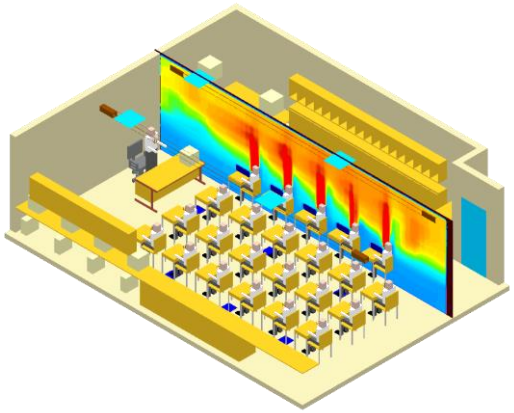


Over Head Air Distribution

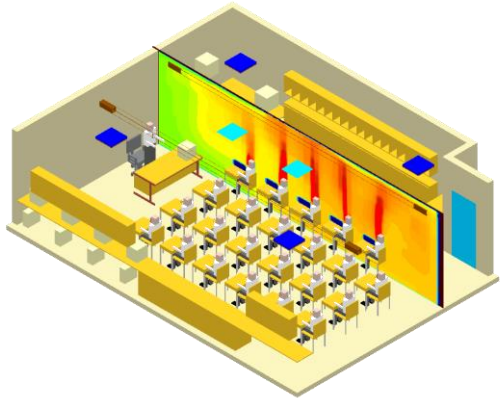


Temperature (deg F)

Under Floor Air Distribution

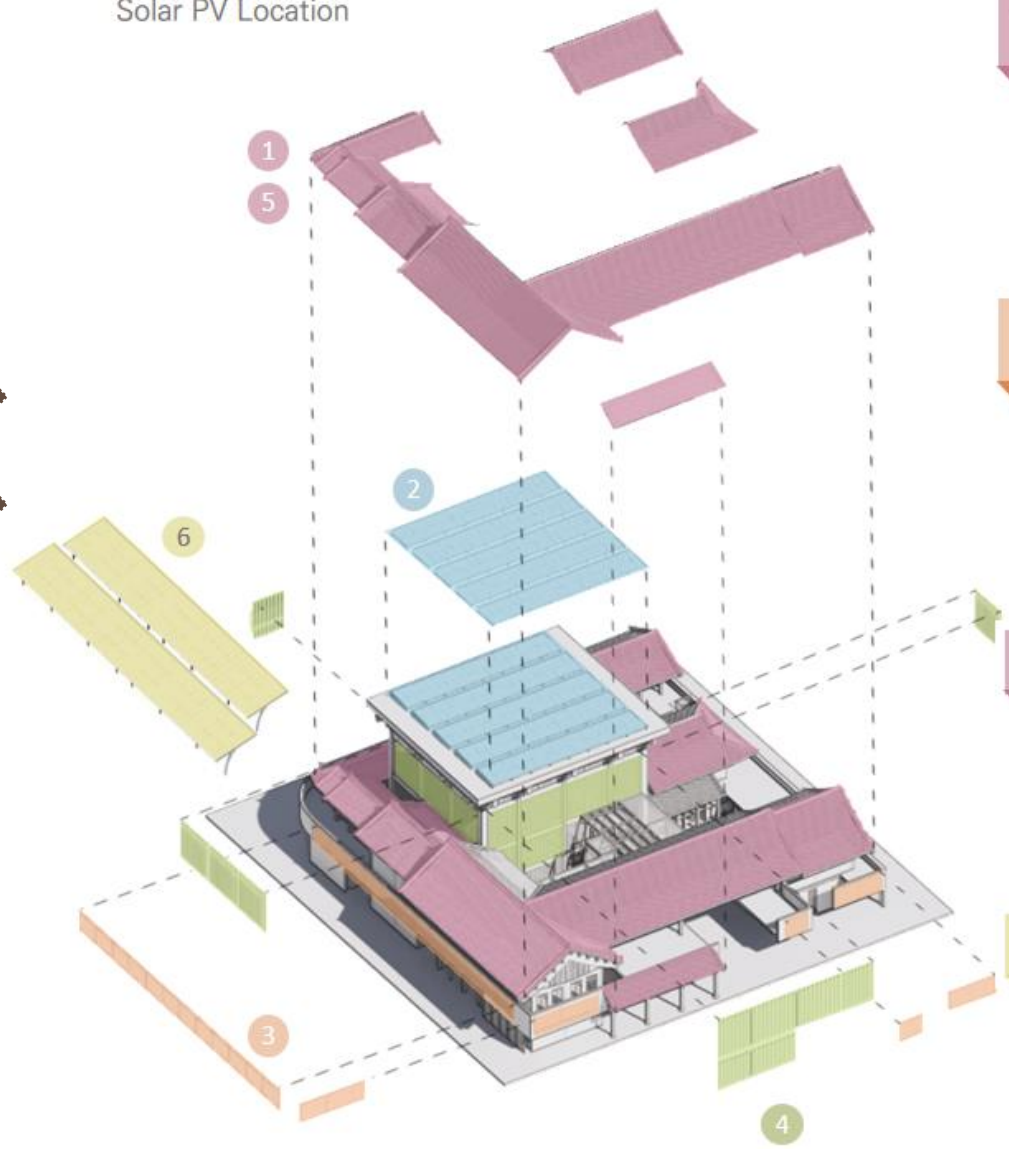


Over Head Air Distribution



Contaminant (ppm)

Solar PV Location



1. PV-Integrated Roof ver.1

Azimuth : 135 , Tilt : 30
Area : 591.01m²
Type : Thin Film
Efficiency : 10%
Array Type : Fixed
DC System Size(KW) : 59.1

2. Atrium Roof PV Arrays

Azimuth : 135 , Tilt : 30
Area : 465m²
Type : Crystalline Silicon
Efficiency : 19%
Array Type : Fixed
DC System Size(KW) : 88.35

3. Wall-mounted BAPVs

Azimuth : 135/225 , Tilt : 90
Area : 39.79m2/92m²
Type : Crystalline Silicon
Efficiency : 19%
Array Type : Fixed
DC System Size(KW) : 7.56/17.48

4. PV-Integrated Vertical Louvers

Azimuth : 90/135/225/270
Tilt : 90
Area(m²) :12.9/74.1/38.8/11.5
Type : Crystalline Silicon
Efficiency : 19%
Array Type : 1-Axis Tracking
DC System Size(KW) : 2.45/14.07/7.3/2.18

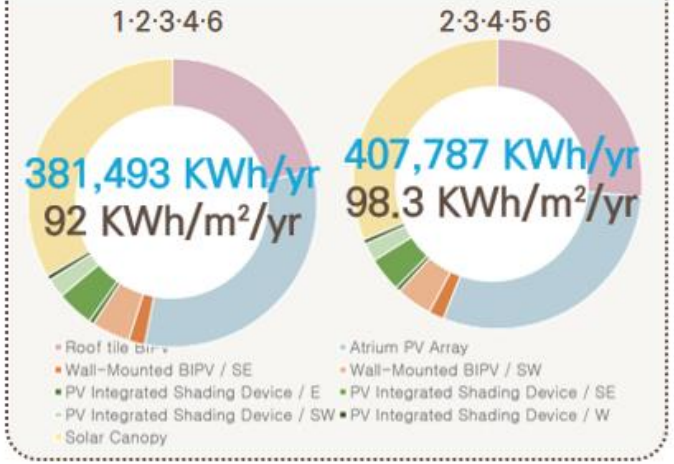
5. PV-Integrated Roof ver.2

Azimuth : 135 , Tilt : 30
Area : 413.7m²
Type : Crystalline Silicon
Efficiency : 19%
Array Type : Fixed
DC System Size(KW) : 78.6

6. Solar Canopy

Azimuth : 225 , Tilt : 15
Area : 492m²
Type : Crystalline Silicon
Efficiency : 19%
Array Type : Fixed
DC System Size(KW) : 93.48

BIPV + BAPV Renewable Energy Generation



Energy Balance

SCENARIO 1: ASHRAE 90.1-2013	
Wall Insulation	0.59 W/m²K
Floor Insulation	0.32 W/m²K
Roof Insulation	0.18 W/m²K
Glazing U-Factor	1.99 W/m²K
Visible Light Transmittance	0.42
Solar Heat Gain Coefficient	0.4
Infiltration Rate	7.2 m³/m²-h
Ventilation Rate	15 L/s-Person
Equipment	25 W/m²
Lighting	10 W/m²

SCENARIO 2: ASHRAE 90.1-2019	
Wall Insulation	0.36 W/m²K
Floor Insulation	0.32 W/m²K
Roof Insulation	0.18 W/m²K
Glazing U-Factor	2.56 W/m²K
Visible Light Transmittance	0.42
Solar Heat Gain Coefficient	0.33
Infiltration Rate	7.2 m³/m²-h
Ventilation Rate	15 L/s-Person
Equipment	25 W/m²
Lighting	10 W/m²

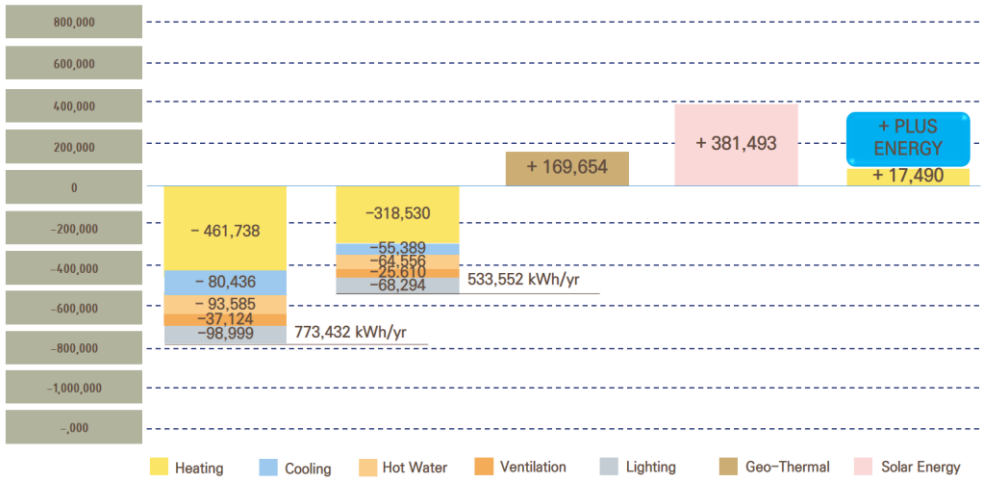
SCENARIO 3: TEAM's STANDARD	
Wall Insulation	0.11 W/m²K
Floor Insulation	0.12 W/m²K
Roof Insulation	0.13 W/m²K
Glazing U-Factor	1.99 W/m²K
Visible Light Transmittance	0.42
Solar Heat Gain Coefficient	0.33
Infiltration Rate	7.2 m³/m²-h
Ventilation Rate	5.5 L/s-Person
Equipment	8.1 W/m²
Lighting	5.3 W/m²

SITE EUI

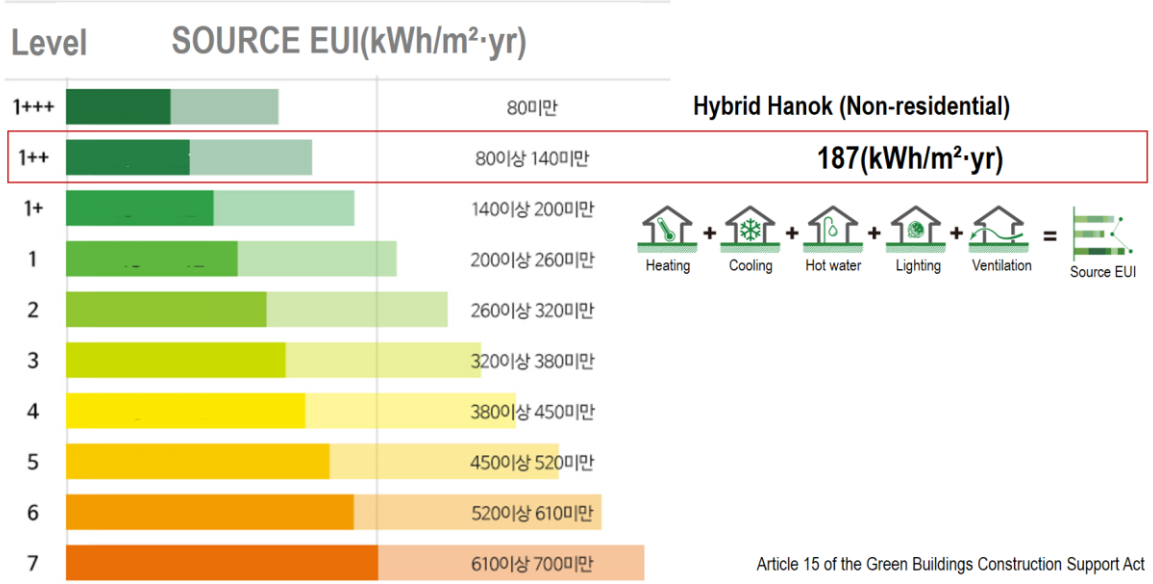
SITE EUI

SITE EUI

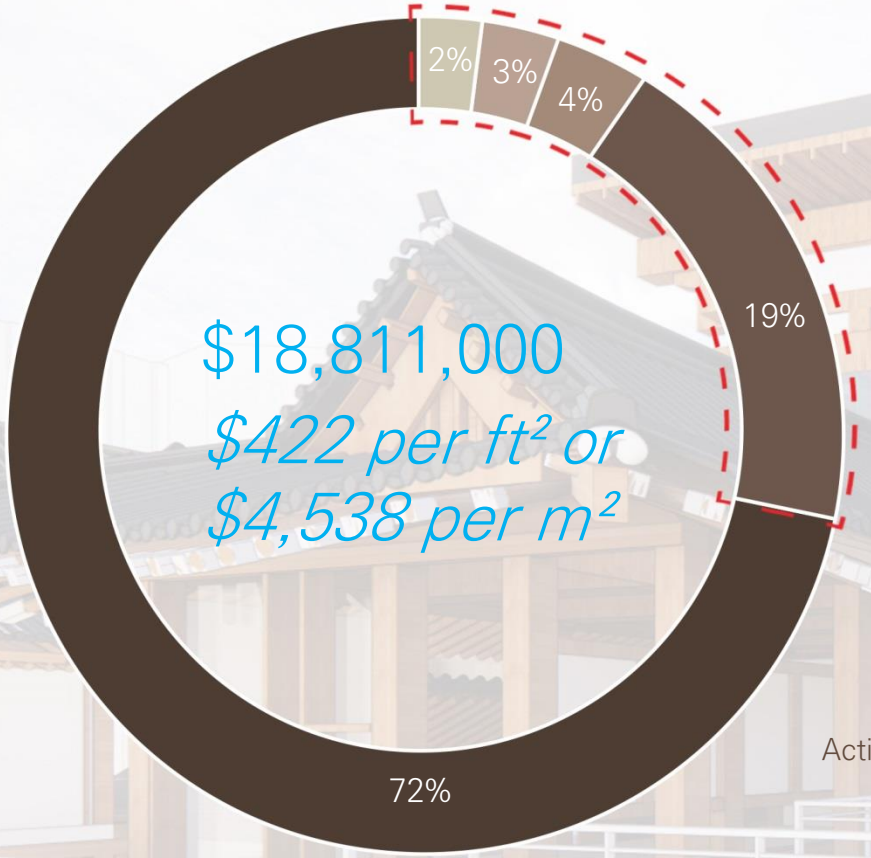
Source EUI	Site EUI	Geo-Thermal	PV Modules	Energy Balance
187 kWh/m²·yr	129 kWh/m²·yr	41.0 kWh/m²·yr	92.0 kWh/m²·yr	-4 kWh/m²·yr



Building Energy Performance Level



Construction Cost Breakdown



Disaster prevention equipment

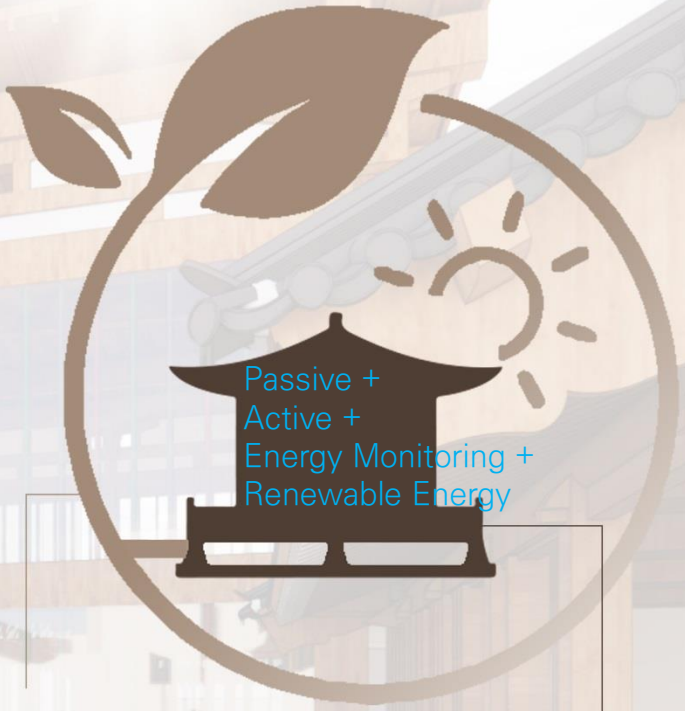
Civil engineering

Energy monitoring system

Active + Renewable energy system

Construction work

Extra Cost for Zero-Energy Hanok



Active + Renewable energy system

Energy monitoring system

Disaster prevention equipment

Hanok construction

+ 33%

Cost by Work Type

Construction works	USD	13,544,064
Active equipment, Renewable energy systems	USD	3,574,128
Energy monitoring systems	USD	752,448
Civil engineering	USD	564,336
Disaster prevention equipment	USD	376,224

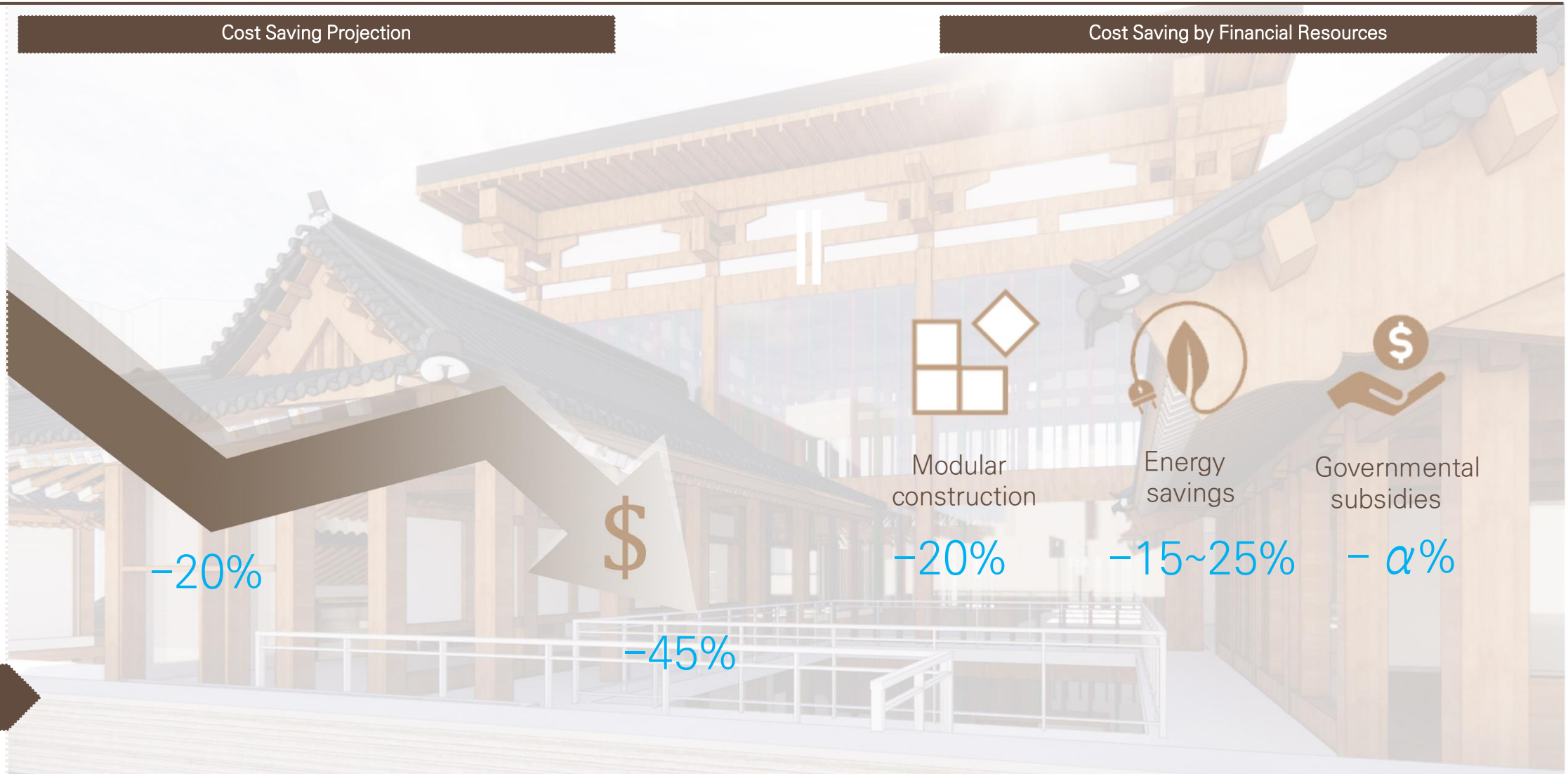
Total Cost

USD 18,811,201

USD 422 per ft² (or USD 4,538 per m²)

(Total floor area : 44,527 ft² or 4,136 m²)

Cost Saving Projection



Cost Saving by Financial Resources

Modular construction

−20%

Energy savings

−15~25%

Governmental subsidies

− α%

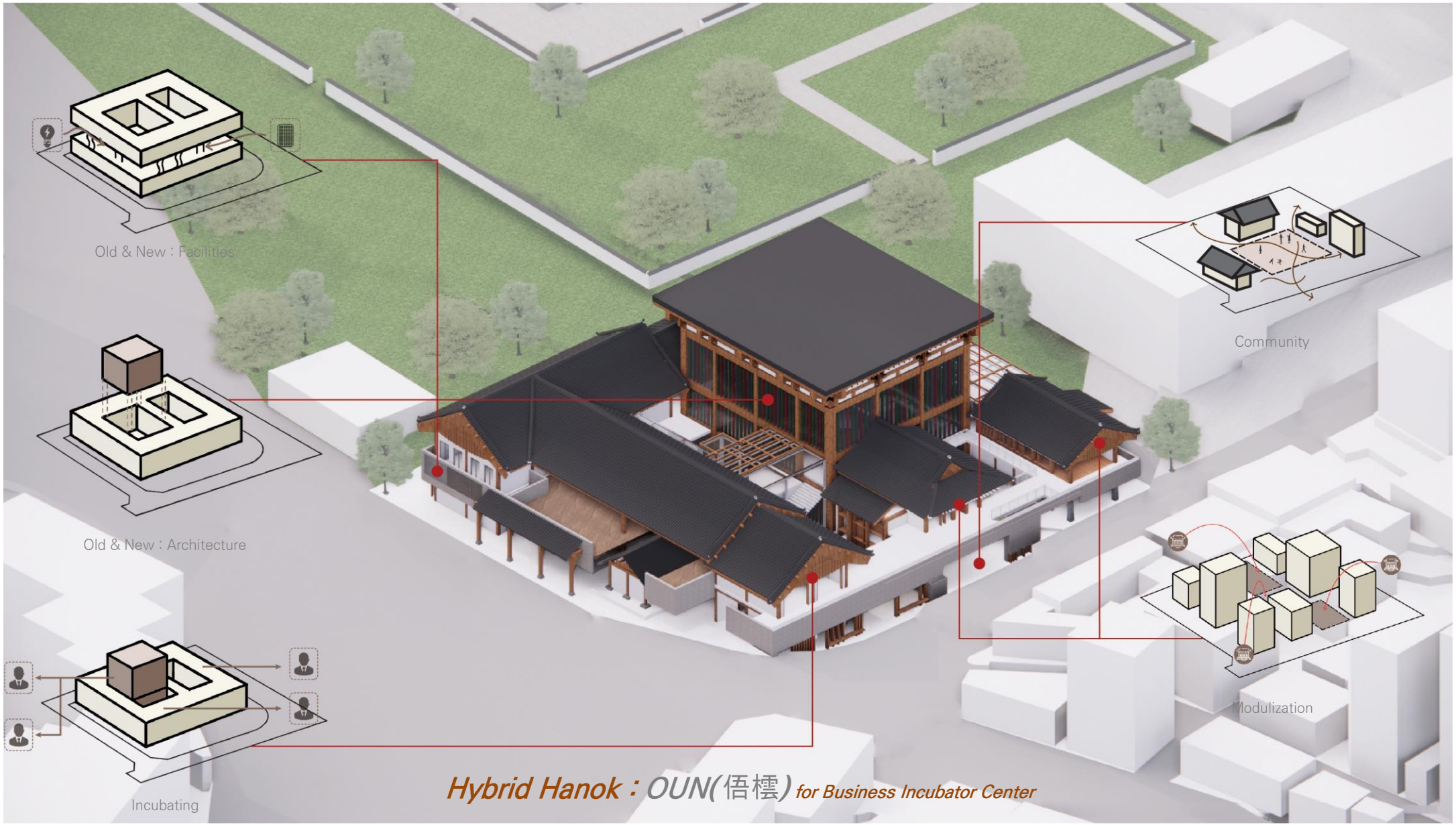
Savings by Plans

Using modular construction saved	USD	3,737,167
Energy savings	USD	4,671,459
Governmental subsidies (2/3 of the construction cost, Max USD 125,365)	USD	125,365

Total Savings

USD 8,408,626

USD 188 per ft² (or USD 2,033 per m²)



CAMU Team

Faculty
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Minkook Kim
Taeseok Kwon
Joonhyeok Seo
Dahyun Lee
JeongHun Cha
Minyoung Kim
Jaekyung Kim
Hyunwoo Rho
Hyeon uk Shin
Ryunhong Kang
Dageon Oh

External Partners

MYONGJI UNIVERSITY CAMU
Consulting for Timber Structure and Materials

AXIAmaterials
Consulting for Envelope Materials and Performances

HAENGLIM
Consulting for Architecture Design

韓國設備研究(株) Han Kook Engineering Co., Ltd.
Consulting for MEP Systems

나무텍 NAMOOTECH
Consulting for Energy Performance and Simulation

Hanok Technology Development Research
Consulting for Hanok Design and Structure

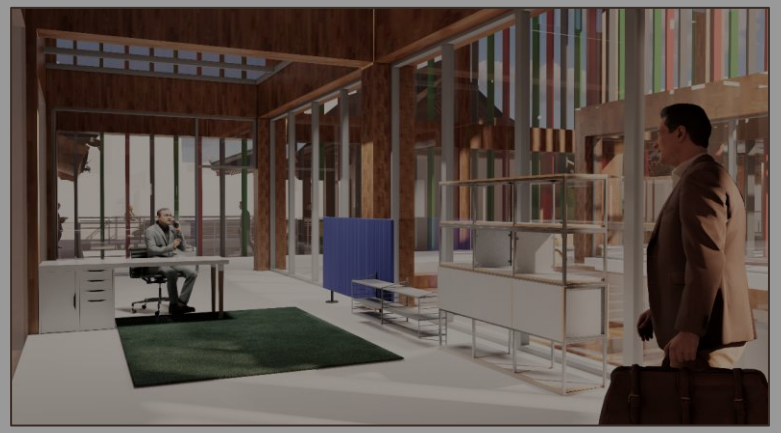
Sep., 2021

- External Meeting w/ HANGLIM & MJ Hanok R&D Center
- External Meeting w/ HANGLIM
- External Meeting w/ AXIA Materials & MJ Hanok R&D Center
- External Meeting w/ HanKook Engr.
- External Meeting w/ Namoo Tech
- External Meeting w/ Namoo Tech & HANGLIM

April. 23 2022

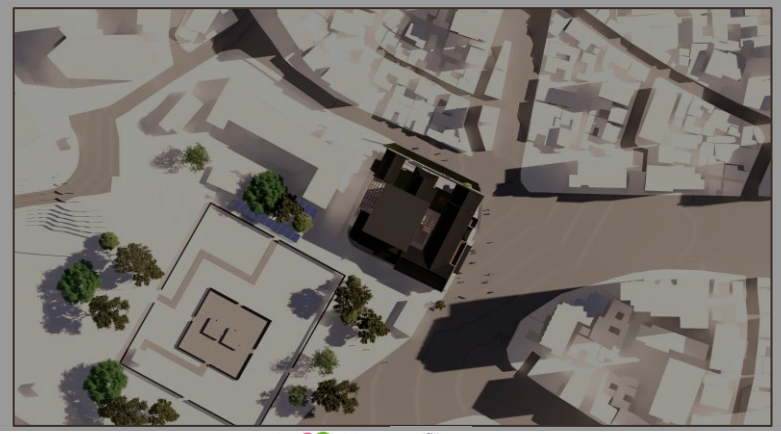
- Internal Kick-off meeting
- Internal Discussion Period: 10/28/21~11/10/21
- Internal Design Period: 11/15/21~1/15/22
- Internal Intensive Production Period: 12/15/21~2/18/22

U.S. DEPARTMENT OF ENERGY SOLAR DECATHLON







Thank you for your listening!